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Rule of Thumb vs. Engineering

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Rule of Thumb *vs.* Engineering.

The familiar Bible sentence says: "He ordereth all things by weight and measure." Granting this to be true, we have the highest justification for the principle known as "engineering," the antithesis of "rule of thumb."

The "engineer" is one who strives to perfect his work, the "artisan" works to get through with it; the first labors for intelligent love of his work, the latter "quits when the whistle blows;" the first puts "grey-matter" into his labor, the latter only muscle and experience.

Ever since man emerged from pre-historic savagery, the one who weighed chances, measured his resources and ordered his actions by intelligent foresight, has earned the place and deserved the title of "the fittest." Engaged as we all are in receiving impressions, recording observations, gaining experience, that man alone is wise who profits by this information to lay down rules for the guidance of his future conduct, for the ordering of his future actions.

The English definition of an inch is that it is "the 12th part of a foot, and equal to three barleycorns." The foot was, of course, originally the average length of the pedal extremities of a race of people and it was not only natural, but inevitable that, for example, the French foot should differ in length from the German foot, etc., etc. Not wishing to pursue this branch of our inquiry to too great and perhaps tiresome lengths, we may as well recite at once a striking and suggestive fact, whose connection with our argument may not be at once apparent; viz., the French word for an inch is "le pouce," which is also the French word for "the thumb." The connection implied is, of course, that an inch, in France, at least, and probably in England also, was originally the length of the second joint of the thumb, which varies less in different people than would at first thought be imagined.

In the absence, therefore, of a proper foot rule marked into inches and fractions, it was customary at one time to measure lengths of small dimensions with the thumb joint and so get an approximation of the number of "thumbs" in a given length. It would be ill-advised, if not conceited, for us to poke fun at or wax sarcastic about the absurdity of such practice, for the "rule of thumb" was a valuable practice when compared with what it displaced—no rule at all; and just as imperfect laws are better than total lawlessness, so the "thumb rule" marked a decided advance towards the arts and sciences.

Somewhere later in time than the period we have been considering, measures of length accurately compared with an arbitrary standard began to multiply and to displace the "rule of thumb." Artisans could then begin to work with exactness, the carpenter could plan and scheme ahead accurately by measure, the smith could forge articles accurately to any required stated size, the gentleman could order from his tailor trousers so many inches long, without allowing for the different lengths of thumb of his sartorial "churls." This period having arrived, and this stage of advancement in the arts and sciences having been reached, we are now prepared to let loose the vials of our criticism, or, perhaps, indignation, and with perfect justification, upon the unlucky wight, who, either from inborn "cussedness" or acquired laziness *continues* to afflict humanity with "the rule of thumb." Here is the unpardonable sin: the accurately divided rule has come, and the confirmed sinner sticks to his "thumbs" and "barleycorns."

Having dragged the reader through this somewhat misty prologue, it is becoming that we state exactly what we mean to talk or preach further about. It is just this: The difference between "rule of thumb" and accurate calculation, the wide gulf separating the hit-or-miss cut-and-try methods of the ancients and the scientifically-informed practice of the modern technologist. Not that we are going to hold up the former to ridicule or the latter to extravagant adulation, but we wish to discuss some of the features of modern technology which illustrate the great change which has taken place and the still greater changes which are possible.

To take an illustration from civil engineering: Spanning the Firth of Forth, a few miles above Edinburgh, stands the greatest structure of the present time. With clear spans of 1,700 feet, capable of carrying the heaviest trains, the strains and stresses in each of its thousands of members all accurately calculated beforehand, here is a monument to engineering skill absolutely unthinkable as a product of "rule of thumb."

To take a mechanical illustration: Down in the hold of a monster steamship, compressed within the smallest possible working space, are engines developing, night and day, 40,000 hp. Every nut, bolt and screw has its assigned place, every accurately calculated and measured part its function, every unequal strain is balanced, economical operation provided by a complex system of quadruple expansion, every one of the thousands of parts all working in complete harmony and under exact control. The triumph of mind over matter, you say; yes, but better as an illustration of the infinite superiority of "engineering" over "rule of thumb."

Look once more at the electrical engineer and his achievements. A huge dynamo spins like a top on a shaft 160 feet deep, and develops in the smallest compass imaginable 10,000 hp. The diameters of the armature wires are accurate to the thousandth of an inch, the hundreds of turns of wire are neither one too few nor one too many, the very phases of the pulsations of the electric waves are mapped and studied out so as to bring out the maximum efficiency. Soft iron from Norway, mica from Canada, rubber from Paraguay, copper from Arizona, shellac from China, steel from Pennsylvania, are combined with the most consummate skill and accurate calculation into a huge giant, which works day and night with almost the regularity of a planet. "Rule of thumb" could never have conceived of such a product; only "engineering skill" has made it possible.

One Art and one Science still bear much of the stigma of "rule of thumb:" the Science of Chemistry and the Art of Metallurgy.

Chemistry remained Alchemy until the invigorating breath of modern methods commenced to blow away the mists of mystery which enveloped it. The evolution has been long and laborious. Conservatism in the managers combined with stubborn old-fogyism in the workman, have conspired against enlightening methods to keep the industry in the rule-of-thumb rut. Germany was the first country to break away into scientific and engineering chemistry, and the lead thus gained has been maintained to this day. The Britisher, workman or manager, is the most conservative of human beings, and his backwardness in following Germany's methods is the chief cause of the industrial difficulties under which the British chemical industry now labors.

Metallurgy is still rule of thumb in many countries, such as Central Africa (production of iron), China (production of lead and mercury), Straights Settlements (reduction of tin), where aboriginal methods still largely survive. But, the aboriginal spirit is preserved in many other so-called civilized countries; it persists among the Cornish and Saxon tin workmen, the Derbyshire and Carinthian lead smelters, the Welsh and Mansfeld copper refiners, the Alaskan and Siberian gold winners, the Missouri and the Silesian zinc distillers, the Almaden and Idrian mercury mines, the Eastern Pennsylvania as well as the Lithuanian blast furnaces.

Among all of these, and others too numerous to mention, are to be found that reverence of tradition, that willingness to keep plodding in the rut, that indisposition to apply the discoveries of modern science, that ignorance of what modern science has disclosed, which keep them groping in the semi-darkness of medievalism, while their more intelligent neighbors are running away from them like an express train distancing a stage coach.

To be more specific, and therefore more to the point, let us catalogue the principal items of this indictment, the details of modern scientific discovery whose neglect is the reason for the preceding Philippic. The broad principles involved are simply—neglect to order "all things by weight and measure;" in other words, neglect of the only means by which *intelligent control* can be exercised over chemical and metallurgical processes, or, in still other words, preference of *rule-of-thumb* to *engineering skill.* These principles can be sub-divided, for further consideration, into the observation and utilization of

(1) Weights.
(2) Compositions.
(3) Volumes.
(4) Pressures.
(5) Thermometry.
(6) Calorimetry.

(1) The first and probably most important method of control, is that of *weight.* The use of the scales, to determine how much material is being used and how much produced, and to regulate the items of charging and discharging a furnace or other apparatus, is so nearly universal that it is with difficulty that we can imagine the chemist or metallurgist doing any work without them. Yet there was undoubtedly a time when both chemical and metallurgical operations were conducted without a knowledge of the weights involved, when it was not known that more pounds of ore must be used than pounds of metal are obtained, and when the most delightful degree of irresponsibility must have been felt by the workman as to the output of his process.

We can feebly imagine the tremendous "kick" made by the first Tubal Cain who was furnished with a pair of scales and told to record the weights of all he used and all he produced. How he would execrate the useless labor involved, condemn the "powers that be" to the Styx for increasing his labor so unnecessarily, and even possibly damage the obnoxious weighing machine surreptitiously if he got the chance.

Yet, such behavior sounds too familiar to be altogether confined to ancient history. Is it not true, that even in our day, the scales are not used as much or as carefully as they should be? To put the indictment in a mild form, are not weights taken too little in detail? For instance, the coal used by a furnace, running continuously, is put into a bin and the amount used per week is accurately known; but, if the weights taken out of the bin were determined for each shift of workmen, it might be determined whether the night shift was as economical of fuel as the day shift or not.

In metal-melting establishments, fluxes are often used much more lavishly and extravagantly than they should be; a careful account of the weights used by each melter for each melt would often illuminate matters. All sorts of extravagancies and negligencies may pass for years unchecked if not controlled by careful weighing, carried out in great detail and for each individual unit. The cost of this slightly greater attention to detail will almost invariably be several times repaid by the increased information acquired and more intelligent control thereby made possible.

(2) The question of compositions is the purlieu of the analytical chemist. How slowly the value of this information is being recognized! Next in importance to the amounts of material being used or produced is their quality, and here rule of thumb has reigned supreme until almost our own day. This ore looks certainly better that that, this fuel is finer than that one, as anybody can tell; that slag is all right, you can't see any metal in it; this pig iron is first quality, just look at the fracture—and so the rule-of-thumb man keeps on delivering dicta, drawn from experience, most of which are right and some of which are egregiously wrong.

The greatest benefactors of chemistry and metallurgy in the nineteenth century were those who developed analytical chemistry into a practical art—such as Berzelius and Fresenius, and those who led in its practical application, such as Bell, Bessemer, Muspratt and Lunge. It is surely unnecessary to give examples of what the analytical chemist has done for all branches of applied chemistry. He has been the principal factor in modern scientific control of all these operations; and the logic of this circumstance is so strong, that the chemist in the works laboratory has become the natural candidate for the superintendency of the plant.

The chemist in the laboratory is primarily a machine to do analytical work; but, granting him only moderate ability, he soon acquires incidentally such intimate insight into the *rationale* of the works' operations that he becomes indispensable out in the works as conductor of those operations.

The chemist should need no recommendation to modern technologists; they should all know by this time how hopeless it is to get along satisfactorily without him. But, there are still some adherents of rule of thumb who think they can; there still exist some foundrymen who believe they can tell good pig iron when they see it (but they cannot), steel workers who can tell the quality of steel from its fracture (they are often fooled completely by modern steels), blast-furnace men who can distinguish good coke from bad by the looks (retort-oven coke contradicts their experience), and so on, through all the range of chemical and metallurgical technology.

The modern way to get scientific control of this question of *quality* is to use the chemist, with his methods of examination—analytical, microscopic, experimental—and so keep going a works laboratory. If it does not pay for itself several times over, it will be through human imperfection in the laboratory or in the management of the works, but not to defect in the principle involved.

In any but large works the chemist will also be the physicist of the plant. He will be looked to to make those physical determinations of volumes, pressures, temperatures and heat distributions which are so badly needed, but so little employed. Incidentally, it may be observed that he is usually, by education and training, more fit to do this work than the mechanical engineer, who is often asked to perform it.

(3) The use of instruments to determine the volumes of gases involved in operating any process, is an improvement which tends away from rule of thumb and towards accurate control. The use of the anemometer to determine the volume of air-supply to a furnace, of the Pitot tube to measure the gas supply in a closed tube, of the draft gauge, plain or multiplying, to estimate resistances to flow and in general all the methods by which the volume and velocity of gas or air currents may be made known, are first aids to the scientific chemist or technologist.

Using forced draft it is possible to measure the delivery of a fan and adapt it exactly to the feed of coal dust so as to produce nearly perfect combustion; many a boiler gives poor results because twice as much air is used as is needed to burn the fuel, causing high chimney losses.

When managers realize, as they should, that such information means, if properly used, stopping of large leaks and obtaining of higher efficiencies, they will be quicker to avail themselves of the more accurate control thereby assured.

(4) In some operations, pressure plays an important part in the operation and should be accurately controlled by properly calibrated instruments. The back-pressure in a blast furnace is known indirectly by the increased work thrown on the blowing engines, but it is much better known by a suitably-placed gauge. An unexpected fall in pressure between two points on a blast main may indicate too small a main or an obstruction or high friction, which might be cured by making the interior smoother. If pressures are involved in any operation, an active use of the pressure gauge is a constant *desideratum.*

(5) Thermometry tells the intensity of heat effects and is being less and less neglected as the methods of pyrometry are being more and more perfected. Nothing is of more importance for any furnace process, than that the temperature conditions should be kept constant or be reproducible at will, and

the only sure control of this is instrumental determination of the temperature.

The human eye, when highly trained, can determine temperatures between a low red and a bright yellow with a considerable degree of accuracy, providing the eye is not fatigued and the possessor of it has a liver in good working order. Good instruments, however, are more accurate, and are less susceptible to fatigue or disorders, while they can be made to register at a distance and even to give a continuous record.

All these improvements have tended to remove empiricism and to replace it by accuracy, to take the control of the operation out of the hands or skill of the workman and vest it in the real manager of the work. Finally, it permits of high-priced skilled labor being supplanted by faithful, but less experienced and lower-priced men, all tending to greater regularity of output and lower cost of production. One of the most satisfactory developments in the last ten years has been the great increase in the number of reliable pyrometers and in their general use. That user of furnace processes who is not equipping his plant with pyrometers is surely allowing his competitor who does, to gain a great advantage.

In the metallurgy of iron, pyrometers have, until recently, been used only on the hot-blast main of the blast furnace. They should be used at the top of the furnace, at entrance to the stoves, at chimney flues and to control temperature of pig iron and slag. They should be used on mixers, puddling furnaces, open-hearth furnaces, bessemers, casting ladles, reheating furnaces, annealing furnaces, cementation and malleableizing furnaces, and for hardening and tempering.

In the metallurgy of copper they should be universally used to control the roasting operation and matting furnaces. In the metallurgy of zinc, the roasting and distilling furnaces will be under better control the more they are investigated pyrometically.

Too high temperatures are often as greatly destructive as too low temperatures are inefficient, and both can be avoided or controlled by the pyrometers. Space forbids the cataloguing of even a fraction of the places and processes wherein pyrometry should be used more largely; it is one of the principle methods of controlling an operation in the hands of the modern technologist.

(6) Lastly, calorimetry measures quantities of heat and tells in what directions the furnace is expending its energy. One boiler may evaporate 8 pounds of water per pound of coal, and another 10 pounds, but when we learn that the heat in the steam is only 40 and 50 per cent, respectively of the calorific power of the fuel, we first become aware of the great room still left for improvement.

Again, a steel-melting crucible delivers as useful heat in the melted steel only some 3 per cent of the calorific power of the coke burned; an open-hearth furnace 25 per cent; a cupola 35 per cent; an electric furnace 50 to 75 per cent of the heat value of the electric energy expended. In all these cases, information of the highest value to the metallurgist can only be obtained by calorometric measurements and calculations based thereon.

When a furnace process is thus analyzed thermally and the distribution of its available heat energy tabulated, so much to radiation, so much to imperfect combustion, so much to chimney loss and so much (usually *so little*) usefully applied, there becomes possible a true esoteric view of the operation.

Only on such broad grounds can the process be thoroughly understood in all its relations and such information opens the way to economies often unthought of before. We therefore plead earnestly for the calorimeter as one of the chemist's and metallurgist's most valuable, and perhaps most neglected, auxiliaries.

The conclusion of our argument is that technologists, in whose hands lies the application of science to human needs, should assist their endeavors and perfect their methods by the use of all the means of attaining *accuracy of control* which science furnishes them; that they should use and profit by the instruments of weighing and measuring masses, volumes, pressures, temperatures and heat; that they should use the analytical chemist more than ever before; and, finally, that by these means only can they reach the goal of the highest attainable efficiency.

The rule-of-thumb man guesses: the engineer calculates.

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